

Reference Models for Production Planning and Control Systems: A Bibliometric Analysis and Future Perspectives

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Abstract— *The activity of modeling business processes is still not a common practice among organizations which contributes to increase the cost and time of systems deployment, improvement projects and educational software, due to the need to develop new models related to Business Processes. In this context, one of the Business Processes essential for organizations, especially those located in countries such as Brazil, where production activities are more pronounced than product development, is Production Planning and Control (PCP). In this scenario, in order to present a picture of scientific production, contribute to the literature review and identify gaps in the scientific literature within the framework of the Reference Models and PCP approach. This work aims to perform a bibliometric research in these areas of study. In this study, we used the bibliometric revision method composed of four phases: definition of database, definition of research keywords, selection of papers and analysis of papers. As a result, it was found that most scientific studies are focused on very specific situations in industrial planning or addressing particular business sectors.*

Keywords— *Reference Model, Bibliometric Analysis Planning and production control.*

I. INTRODUCTION

Modeling the processes of a company provides a better understanding of the assumptions regarding the management inherent in its systems and, also, and also viable alternatives to existing organizational activities, in order to provide an effective framework for decision-making (CORREA; SPINOLA, 2015).

Based on a reference model, it is possible to analyze the best use of its industrial potential, in order to obtain more

effective answers to the constant changes that have occurred in the market. However, the business process modeling activity is not yet a common practice among organizations, which contributes to the increase in cost and time of system implementation or improvement projects, due to the need to develop new models related to their Business Processes (BREMER; LENZA, 2000).

In the business context, one of the most important business processes for organizations, especially those located in countries such as Brazil, where production activities are more pronounced than product development, is Production Planning and Control (PCP).

According to Thurer & Filho (2012), most companies are aware that they must improve their PCP activities in order to achieve reductions in lead time and work in process, thereby achieving greater operational efficiency. However, for the authors, especially small and medium-sized organizations, simply do not know how to do this, since the vast majority of research and solutions for PCP are focused on large and complex companies.

Therefore, it is important to note that there is an academic gap regarding work to support the implementation of PCP systems. In addition, there is a great and growing attention, both in academia and in business, in the development of models that support the planning of business resources (CORREA; SPINOLA, 2015). However, studies found in the literature focused on the development of PCP models are mostly oriented to particular industrial segments and that address modules of specific activities of Production Management, as observed in the papers published by Ji, Wang and Hu (2016), Mariel and Minner (2015), Carvalho and Pacheco (2014), Lu et al. (2013) and Costa e Silva (2010).

In this way, in order to present a picture of the scientific production, contribute to the literature review and identify gaps in the scientific literature within the framework of the Reference Models and PCP approach, this work aims to perform a bibliometric research in these areas of study. The paper is organized as follows: Section 2 discusses the literature review on Reference Models and PCPs, section 3 deals with the applied methodology of bibliometric revision, section 4 presents the study performed and the results obtained, and finally section 5 presents the final considerations.

II. REVIEW OF LITERATURE

II.1 Reference Model

Reference modeling is defined as the process of formally documenting a problematic domain in order to understand and communicate stakeholders (SIAU; ROSSI, 2011). The reference models, which can be developed in real situations or in theoretical studies, document the various aspects of a business process. According to Bremer and Lenza (2000), the purpose of reference model is to provide the company with an initial solution for its Business Processes, so that, through it, the particular model of the company is specified and detailed. For the same authors, these models, through documentation, storage and use of knowledge, are key instruments in the process of management of educational learning.

For Vernadat (1996), a reference model must contain a certain degree of generality and be customizable. Therefore, For Vernadat (1996), the reference model must contain some degree of generality and be customizable. Therefore, it should serve as a basis for discussion, a formal or semiformal suggestion for the elaboration of specific models, bringing information regarding to the business process design.

Keller e Teufel (1998) understand that the reference models can be applied in cases of accumulated experience in a type of business, and can be applied to business process solutions implemented and executed in enterprise management software.

The reference models can be distinguished between procedural models, or standard software implementation, and business models (models for production management and product development). Bolloju and Leung (2006) suggest that during the analysis phase of an information system development, the reference model can be used to capture and represent the requirements of development and deployment of such technologies.

According to Climent, Mula and Hernández (2009), reference models are useful in describing and graphically representing important aspects of a particular process, distinguishing, for example, people, departments and the connection between them. In addition to Vergidis, Turner,

and Tiwari (2008) the models adequately portray and represent processes, emphasizing the aspects that need to be communicated and addressed.

In a review elaborated by Hernandez, Mula e Ferriols (2008), it was proposed that a reference model describe the social and physical aspects of the world in order to understand and communicate. Supplementary, it has also been described that the reference model must go beyond the terms "specifications" and "requirements" and apply three linguistic concepts (syntax, semantics and pragmatics) to four aspects of modeling: language, domain, model and participants.

Tsai and Sato (2004) proposed a reference model in UML notation called by the authors of the Agile Production Planning and Control System (APPCS). The authors created a model of PCP in order to develop a system contemplating the following functions: material requirements planning; task-oriented programming / operations; purchasing; and production control. Bremer and Lenza (2000) have developed a reference model through academic research on production management, of practical work developed and by interviews with companies.

Briefly, the advantages to be attributed to these models consist in reducing the time and cost in the development of particular model; comparing the activities of the company with the activities proposed in the model, that is, best practices; and better support in deploying x integrated business management systems teaching support software.

II.2 Planning and production control

PCP is an administrative function whose purpose is to accomplish the plans that guide production and serve as a guide for its control, aiming to increase efficiency and effectiveness through the management of what is to be or is being produced, in order to satisfy consumer demand (ANTUNES; SEHNEM; LIMA, 2014).

PCP systems are responsible for defining how the organization should follow to achieve its strategic objectives supporting the decision-making of managers, mainly on the following issues: what to produce, how much to produce, when to produce, and with what resources to produce. Thus, it can be said that this system dictates the rhythm of the production in the company and can be considered as one of those responsible for a fundamental competitive advantage: the quality of the goods produced.

Still according to Fernandes and Filho (2010), Production Planning deals with aggregate decisions in a medium-term universe. Production Control is responsible for regulating (planning, coordinating, directing and controlling), in the short term, the flow of materials into a

production system through information and decisions to execute.

For Andrade and Fernandes (2015), PCP is an activity that consists in the establishment of an operational plan, being worried about managing the activities of the productive operation such as to meet the demand of consumers. For the authors, the PCP provides information for the efficient management of the flow of materials for the effective use of people and equipment available for the coordination of internal activities with those of external suppliers and for an effective communication between the needs of the consumer market and the productive system.

A quantitative case study performed by Fernandes et al. (2013), seeking to improve the management of a production line, showed that the productive processes were optimized queues and lead time were reduced, after the implementation of an effective PCP system.

III. RESEARCH METHOD

Bibliometrics provides statistical metrics related to the study of quantitative processes of production, dissemination and use of information and also designates advanced processes and mechanisms of online search and information retrieval techniques, being important tools for management of teaching and knowledge, once that it is possible to detect gaps in the scientific literature (BUFREM; PRATES, 2006).

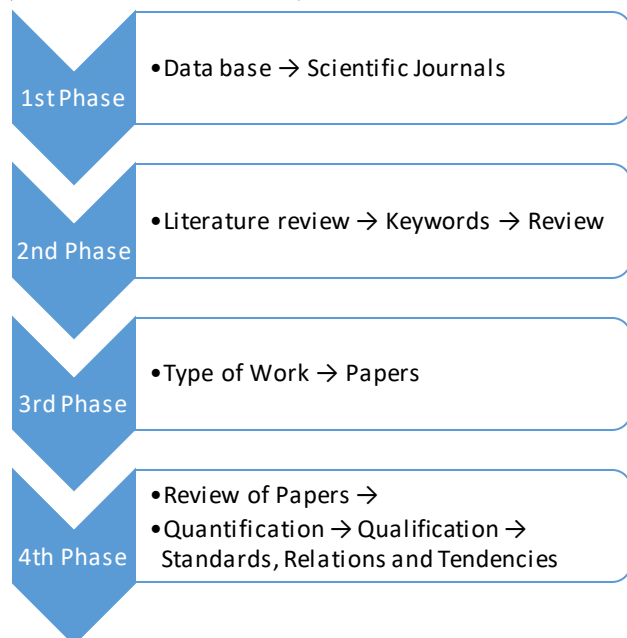


Fig. 1: Flow chart of methodology to be applied in the bibliometric review.

This research can be considered theoretical and conceptual and is focused on the bibliographic analysis to be carried out through a structured review of the

literature, aiming to analyze the Reference Model theme from the PCP point of view. Will be used the method of bibliographic revision, proposed by Marasco (2008), with four different phases (definition of database, definition of research keywords, selection and analysis of papers), as shown in Figure 1.

In the first phase for the composition of the bibliographic portfolio, the SciVerse Scopus databases were defined. The choice of this database is due to the fact that it encompasses the journals that most publish research related to Production Engineering (MARASCO, 2008). Although the results and conclusions from this research are limited to the selected database, the ideas presented in this paper contribute to the development of the field of knowledge and can serve as inspiration for the development of new knowledge, both for academics and professionals in the field of PCP.

Surveys were conducted in journals without temporal delimitation of published studies. The total amount of works found in the mentioned databases was a result of the combinations of keywords searched in the titles and in the summaries of the papers. The research was conducted in January of the year 2018.

In the phase of definition of keywords for the bibliographic review, from the SciVerse Scopus database, the following keywords were used: "Production Planning" OR "Production Planning and Control" AND "Reference Model".

These terms were submitted to the selection filter, which included the inclusion criterion by reading the title, summary and keywords. This search resulted in a sample of 18 papers published in the subareas Business, Management & Accounting and Engineering, main fields of research on this subject. Subsequent to the definition of the sample, the data available in the SciVerse Scopus database were extracted as: authors, title, journal, year and number of citations.

In the analysis of citations of papers collected at the SciVerse Scopus database, two activities are presented: calculation of the corrected index of citations and ordering of the most cited papers. Equation 1 shows the calculation of the Corrected Citation Index (CCi), in which the CI is the citation index extracted from the database and IF is the impact factor of the journal in which the paper was published (IRITANI et al. 2015). According to Lopes and Carvalho (2012), the correction of citation index aims to contain, in addition to the number of citations, the relevance of the journal in which the paper was published.

$$CCi = CI \times (IF + 1) \quad (1)$$

IV. RESULTS AND DISCUSSION

The first analysis of publications was that of journals per year, in which it was possible to identify the evolution of the publications of papers focused on the study and development of reference models for PCP environments.

Figure 2 shows the evolution chart of the number of publications over the years according to the Scopus database. It is observed that few studies that simultaneously approach the concepts of Reference Models and PCP have been published over the last 30 years, which shows that this area of study still has many aspects to be explored.

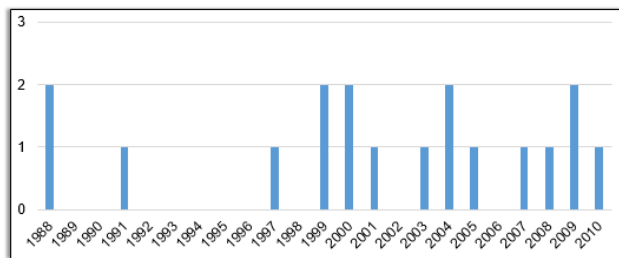


Fig. 2 Evolution of the number of publications over the years in the Scopus database.

It is also worth noting that in the last ten years only five studies focused on this theme were produced, the last one being published in 2010. The following are the most recent works in the areas of reference models and production planning:

- Abele and Schrems (2010) proposed, based on a reference model, a software tool that helps the production engineer to choose the most efficient production techniques. This tool is based on a methodology to calculate the anticipated consumption of energy and resources of different process techniques.
- Aguilar, Chacal and Bravo (2009) developed a general reference model for automated applications, which perform production planning functions and production factor management. Then, this reference model was used to propose a model for the ERP system based on multi-agent systems.
- Martinez-Olvera (2009) proposed a reference model on-demand manufacturing environments (MTO – Make-To-Order). The MTO-based reference model was presented through IDEF notation and was derived from domain knowledge in the manufacturing execution area.
- Hernandez, Mula and Ferriols (2008) proposed a reference model for the conceptual modeling activity of production planning processes, from the description of a methodology for the identification and analysis of inputs, outputs, processes and subprocesses.

- Aviv (2007) studies the potential benefits of Collaborative Forecasting (CF) in a supply chain consisting of a manufacturer and a dealer. To reflect reality in production environments, the author proposed performance indicators that captures inventory and production considerations and adherence to plans. Finally, a prescriptive and convex production planning model was presented for the manufacturer and a spare model for the dealer. The integrative reference model was used to study the potential benefits of CF partnerships.

Among the 36 authors surveyed, the authors who published the most are shown in Figure 3.

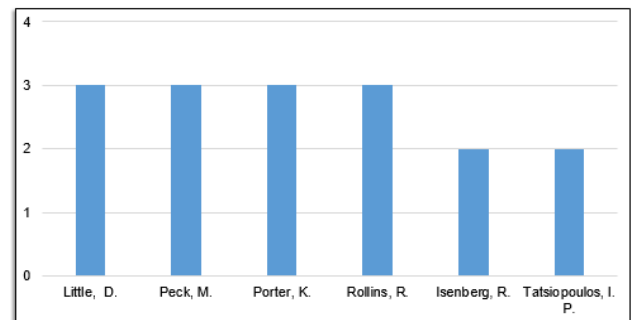


Fig. 3: Quantitative publications of the main authors in the Scopus database.

Following are the papers published by the main authors in the area of reference models in PCP systems according to the Scopus database:

- Little et al. (2000, 2001) concluded research based on case studies aimed at the development of new planning reference models for industrial sectors where MRP II was not appropriate. for data capture in the companies where the case studies took place and the use of ARIS for the production of sector reference models. However, according to the authors, the reference models are determined for a specific industrial sector.
- Porter et al. (1999) presented a review of some common manufacturing classification systems, and attempted to direct them against accepted paradigms for production planning and control approaches. The authors also discussed a method for mapping production processes, with the objective of creating a series of reference models for the PCP.
- Isenberg (1988) described the analysis, design, and implementation of a work cell controller that uses knowledge-based system technology in the electronics industry. The central task of the work cell controller was to fill the gap between the high-level PCP system of the logistics department and the short-term planning at the shop floor level through the use of reference models.

- Meyer, Isenberg and Hubner (1988) also presented a unified methodology for analysis, design and implementation of software modules as experienced systems for production planning, quality control and preventive maintenance. It was also selected by these researchers an extension of the hierarchical reference model for a distributed intelligent controller model.
- Tatsiopoulos and Mekras (1999) presented a specialized rule-based system that can be used to select a package of suitable PCP software to be applied in a specific manufacturing company. A tipologia do sistema de produção e um modelo de referência de software PCP
- The typology of the production system and a reference model of PCP software Tatsiopoulos (1997) presents a data-oriented reference model for the order-release process that forms the link between the PCP system and the production execution system. A generic architecture is described in the form of a module structure which includes: order manager, material manager, and capacity manager. The architecture is further decomposed into a data model layer and a function layer creating a reference model with generic, partial, and particular views.

Table.1: Shows the list of extracted, in descending order of the number of citations, at the Scopus database, specifying the number of citations and the that was published, impact factor and the citation index ran.

Table 6. List of papers and their respective CI, IF, e ICc

¹. CI – Citation Index; %CI – Relative Citation Index RCI; JIF- Journals Impact Factor (2016); CIC – Citation index corrected.

Paper	Journal	CI	JIF	CIC
Aviv (2007)	Management Science	89	2,822	340,158
Brinke et al. (2000)	International Journal of Production Research	21	2,325	69,825
Hernandez, Mula e Ferriols (2008)	Production Planning and Control	16	2,369	53,904
Meyer, Isenberg e Hubner (1988)	International Journal of Computer Integrated Manufacturing	11	1,949	32,439
Persona,	Journal of	30	-	30,000

¹ Impact Factor for the year 2016.

Regattieri e Romano (2004)	Manufacturing Technology Management			
Tatsiopoulos (1997)	Computers in Industry	8	2,691	29,528
Porter et al. (1999)	Integrated Manufacturing Systems	27	-	27,000
Bertolini et al. (2004)	Journal of Enterprise Information Management	12	-	12,000
Tatsiopoulos e Mekras (1999)	Production Planning and Control	3	2,369	10,107
Singh e Hindi (1991)	Journal of Intelligent & Robotic Systems	4	1,512	10,048
Martinez-Olvera (2009)	International Journal of Production Research	3	2,325	9,975
Aguilar, Chacal e Bravo (2009)	Computer Systems Science and Engineering	5	0,348	6,740
Abele e Schrems (2010)	ZWF Zeitschrift fuer Wirtschaftlichen Fabrikbetrieb	4	-	4,000
Little et al. (2001)	Integrated Manufacturing Systems	4	-	4,000
Little et al. (2000)	Production Planning and Control	1	2,369	3,369
Ayhan (2005)	Industrial Diamond Review	2	0,138 ²	2,276
Vosniakos (2003)	International Journal of Mechanical Engineering Education	2	-	2,000
Isenberg (1988)	International Journal of Advanced Manufacturing Technology	0	2,209	0,000

² Evaluation related to the year 2007 (last evaluation performed).

The work of Aviv (2007) stands out for having published in a journal of great relevance and world qualification, besides having a high index of citation. Also highlighted in this requirement is the paper published by Brinke et al. (2000). Based on the product information structure related to the Production Engineering reference model, Brinke et al. (2000) proposed a method for estimating costs based on variants. This structure defines a product in terms of elements and their relations. The elements and their properties constitute characteristics of the product that can be used to compare products. For proper use in different engineering processes, product characteristics are related to the four cost requirements: geometry, material, processes and production planning.

Finally, below are the other papers that compose the bibliographic portfolio from Scopus database:

- Persona, Regattieri and Romano (2004) developed a work that aimed to identify the general requirements and guidelines for the definition of an integrated order model for the delivery cycle in an environment with high variety and relatively low volumes.
- Bertolini et al. (2004) defined the main characteristics of a corporate model for the fashion industry. The characteristics required by the ERP model were identified, with specific attention to the PCP modules.
- Vosniakos (2003) described a model to teach the concepts and practical aspects of the integration of manufacturing systems for mechanical engineers.
- The approach adopted took into account six areas of computer-based manufacturing systems: design, production planning, process planning, material control, store scheduling and quality assurance.
- Ayhan (2005) presented a reference model to optimize PCP specifically for the marble industry by calculating production costs.
- Singh and Hindi (1991), as a contribution to the debate on reference models derived from concepts of control theory, formulated the basic problem of management of computer-assisted production from the point of view of control theory and examined the main difficulties in using gross basis as a basis for decision making.

An accomplished bibliometry will be able to discover how the characteristics of publications of the field and, with this, to visualize the scientific scene, the main authors and works, the most relevant journals and the distinctive features that integrated the studies carried out, which helps in the elaboration of dissertations and papers, since it is possible to analyze

the existing gaps in the scientific literature of a given area of research.

With regard to reference models in PCP systems, it was observed that such models prove to be a viable tool to support the development, selection or adoption of integrated management systems and software, as could be seen in the works of Abele and Schrems (2010), Aguilar, Chacal and Bravo (2009), Tatsiopoulos and Mekras (1999) and Meyer, Isenberg which are available in the SciVerse Scopus database. However, it was noticed that most of the studies are focused on very specific situations of industrial planning (AVIV, 2007; LITTLE et al., 2000, 2001; MARTINEZ-OLVERA, 2009; PERSONA; REGATTIERI; ROMANO, 2004) or address particular business sectors (AYHAN, 2005; BERTOLINI et al., 2004; VOSNIAKOS, 2003). This situation has also been verified, as previously mentioned, in the works published by Ji, Wang e Hu (2016), Mariel e Minner (2015), Carvalho e Pacheco (2014), Lu et al. (2013) e Costa e Silva (2010). Additionally, it was found that there were no studies on reference models for support in the development of educational software in the area of PCP.

V. CONCLUSION

Bibliometric analysis is a starting point regarding the characteristics of science in the area of PCP and Reference Models. In this sense, the bibliometric study of the bibliographic portfolio consisted of the analysis of the set of papers for the structuring of an information frame and the scientific knowledge about the researched topic. Thus, this study supports the elaboration of new scientific works (dissertations and papers), since it is possible to analyze the existing gaps in the scientific literature in the area of reference models in the PCP system.

According to the SciVerse Scopus database, the models developed by the extracted works proved to be viable in supporting the development, selection and adoption of integrated management systems and software. However, most of these studies are directed at very specific situations in industrial planning or addressing particular business sectors.

As gaps in the scientific literature, it was verified that there were no studies regarding reference models for support in the development of software to support teaching in the area of PCP.

Faced with this scientific scenario in the area of reference models and PCP, it is suggested as a proposal for future works, the development of a conceptual, holistic and hierarchical reference of activities related to a complete PCP system, in order

to advance international business planning models. Another application found for this model of reference is the teaching of production management, for example, from the elaboration of educational software. undergraduate course in Production Engineering.

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